Design of a Power Control MAC Protocol for Mobile Ad Hoc Networks

A thesis submitted in partial fulfillment
of the requirements for the degree of

Master of Technology

in

Computer Science and Engineering

by

Prejil P

Department of Computer Science and Engineering
National Institute of Technology Rourkela
Rourkela, Odisha, 769 008, India

May 2011

Design of a Power Control MAC Protocol for Mobile Ad Hoc Networks

A thesis submitted in partial fulfillment

of the requirements for the degree of

Master of Technology

in

Computer Science and Engineering

by

Prejil P

(209cs1075)

under the guidance of

Prof. Suchismita Chinara

Department of Computer Science and Engineering

National Institute of Technology Rourkela

Rourkela-769 008, Odisha, India

May 2011

To my parents

Department of Computer Science and Engineering
National Institute of Technology Rourkela
Rourkela-769 008, Orissa, India.

Certificate

This is to certify that the work in the thesis entitled ***Design of a Power Control MAC Protocol for Mobile Ad Hoc Networks*** by ***Prejil P*** in partial fulfillment of the requirements for the award of the degree of Master of Technology in Computer Science during session 2010-2011 in the department of Computer Science and Engineering, National Institute of Technology Rourkela is an authentic work carried out by him under my supervision and guidance. To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/Institute for the award of any Degree or Diploma.

Place: NIT Rourkela
Date: 20 May 2011

Prof. Suchismita Chinara
Assistant Professor
Dept. of Computer Science & Engineering
National Institute of Technology
Rourkela-769 008, Odisha (India)

Acknowledgment

First, I would like to express my heartfelt gratitude to my supervisor Prof. Suchismita Chinara for her guidance, encouragements and support throughout my research at the National Institute of Technology, Rourkela. She helped me in finding research topics, proposing solutions and verifying results. Without her endless efforts, knowledge, patience, and answers to my numerous questions, this research would have never been possible. It has been a great honor and pleasure for me to do research under her supervision.

I would like to thank Dr. Ashok Kumar Turuk, Head of the Department, Computer Science engineering, National Institute of Technology, Rourkela for his support during my work.

I am also thankful to Dr. S. K. Rath, Dr. S. K. Jena,Dr. B. Majhi,Dr. D. P. Mohapatra, Dr. R. Baliarsingh, Dr. P. M. Khilar,Prof Bibhudatta Sahoo,Prof Kora Sathya Babu,Prof M N Sahoo and Prof S Mohanthy for giving encouragement during my thesis work.

I would like to thank all of my colleagues and friends for their inspiration and help.

I thank all the members of the Department of Computer Science and Engineering, and the Institute, who helped me by providing the necessary resources, and in various other ways, in the completion of my work.

I would like to thank my parents for their encouragement, love and friendship.

Finally, I thank god for everything.

Prejil P

Abstract

Power conservation is a major issue in Mobile Ad Hoc Networks, as most of the nodes are battery powered. Power control is not related to any particular layer, since we can apply power conservation methods in all layers. But most of the power control mechanisms are working in MAC layer.

Here we designed a Power Control MAC protocol for MANET. Our first aim was to control the overall power consumption and the second was improve the throughput of the network. Thus our protocol includes two phases; in the first phase we reduce the power consumption and in the second phase we improve the aggregate throughput of the network. Our work is based on the IEEE 802.11 MAC protocol. We added an additional field to the RTS and CTS control packets (PRTS in RTS packet to indicate the power used to send RTS packet and PData in the CTS packet to indicate the power with which sender can send DATA packet) for the design purpose. For reducing the power consumption we used the following method: We send the RTS packet with maximum or default power. The receiver after receiving the RTS packet calculate the data transmission power PData using the received power Pr , RTS transmission power PRTS and the receiving threshold Rth. After calculating the PData that power is assigned to the PData field of the CTS frame and then the CTS frame will send with the same power PData. Then after receiving the CTS frame the sender will send the DATA frame using the power PData and the receiver will send the ACK packet with the same power. In the second phase we have to improve the throughput of the network. For that purpose we made some modifications in the virtual carrier sensing mechanism. We used a NAVR with NAV to make the VCS scheme suitable for our protocol. It make more nodes to send packets at a time and thus improves the spatial reusability. The improvement in spatial reusability increases the aggregate throughput of the network.

Contents

List of Figures

List of Tables

Chapter 1

Introduction

Chapter 1

Introduction

1.1 Introduction

Since the devices used in an ad hoc network are mostly battery powered, power conservation is a major issue of such networks. The following principles may serve as general guidelines for power conservation in MAC protocols [1, 2]. First, collisions, a cause of expensive retransmissions should be avoided as far as possible. Second, the nodes should be kept in standby mode or sleep mode whenever possible. Third, instead of using the maximum power, the transmitter should use a lower power that is enough for the receiver node to receive the transmission. In this context we mentioned above, the MAC protocols can be classified into two: Power management protocols (using alternative sleep and wake up modes for nodes) [2–5] and power control protocols (variation in transmit power) [6, 7]. The nodes in the ad hoc network remain in one of the three possible states: active, idle or sleep. Power consumption in sleep state is less compared to other two states. So we keep some of the nodes those are not participating in data transmission in sleep mode. In a network power is consumed during computation and transmission of packet, but computation power is negligible as compared to transmission power cost. Hence efforts are made to control the transmission power by incorporating different power control mechanisms.

In this thesis we have designed a MAC protocol for reducing the power consumed by each and every node. This protocol also increases the aggregate throughput of the network. The power control approach discussed above is used for the design of the protocol. For improving the throughput, we should improve the spatial reuse of the network. We achieved this by make some modifications in the VCS scheme used in IEEE 802.11. Improving the spatial reuse allows more nodes to send frames at a time and which will increase the overall throughput of the network.

1.2 Motivation

Mobile Ad Hoc networks find its applications in many areas and are useful for many cases. But it faces some problems due to limited battery power of the mobile nodes. Since all mobile nodes are battery powered, we have to use the power efficiently. We can reduce the power consumption by controlling the power used to transmit the different control and data packets. A disadvantage of the power control protocols is the degradation in the network throughput. The objective of this thesis is to reduce the power consumption of mobile nodes and also improve the aggregate throughput of the network. We mainly focus on the power control techniques and techniques for improving the spatial reuse of the network.

1.3 Related Work

Most of the existing power control MAC protocols use the maximum power to send the RTS and CTS packets and minimum power for the DATA and ACK packets. We consider these schemes as the BASIC power control protocol. The protocol discussed in [7], The PCMA protocol, allows different nodes to send packets with different transmission power levels. PCMA uses the busy tones instead of RTS-CTS scheme to avoid the hidden terminal problem. If a node wants to transmit a packet, it senses the channel for busy tones from other nodes. The strength of busy tones received by that node is used to determine the highest power level with which a node can send without interfering other transmissions.

Some principles for the design of a power control MAC protocol is discussed in [8]. Different factors that affecting the power control are also discussed in this paper.

Due to asymmetric links, there may be chance for collisions at transmitter and receiver. The protocol discussed in [9], ALCA reduce it by conveying the CTDI through physical duration of carriers that transport RTS/CTS frames. ALCA provides a discrete se of n different carrier durations for RTS and CTS frames. Terminals located in carrier sensing zone use the carrier duration information to extract CTDI and hence avoid collision. In the PCM protocol [6], the authors make some modifications in the basic power control protocol. Here source and destination node transmit the RTS and CTS using maximum power. Nodes in the carrier sensing zone set their NAV for EIFS duration when they sense the channel busy and cannot decode it correctly. The source node will send the DATA using the required power only. To avoid the collision with the ACK, the source node will transmit DATA at maximum power periodically for enough time

F-PCM protocol [10] have used the fragmentation technique. A large DATA packet is fragmented into several small fragments and the ACK packet corresponding to each fragment is transmitted at maximum power. For each fragment transmission, maximum power for duration at the beginning of fragment transmission thus reduces collision at the sender. ACK for each fragment transmitted with maximum power will reduces collision at receiver.

A power controlled dual channel (PCDC) MAC protocol proposed in [11] allows the MAC layer to indirectly influence the routing decision at the network layer by controlling the power level of the broadcasted RREQ packets to produce power efficient routes. PCDC uses the signal strength and the direction of arrival of the overheard RTS or CTS packets to build a power-efficient network topology. PCDC enables simultaneous interference-limited transmissions to take place in the vicinity of a receiver by allowing a receiver-specific, dynamically computed interference margin.

In [12], the authors have proposed a novel MAC scheme with power control in wireless ad hoc networks. They divide the total channel into three parts: main channel for RTS and data packets, transmitter busy tone channel and receiver busy tone channel. Other two channels are separated with enough spectral intervals.

These two channels indicating whether the node is transmitting RTS packets or receiving data packets. A transmitter busy tone is used by the RTS packet to increase the probability of successful RTS reception and the receiver busy tone is used to acknowledge the RTS packet and protect for the data packet continuously. Here, they transmit RTS and data packets with the same power. A sender which wants to transmit a packet will sense both transmission busy tone channel and receiver busy tone channel. If they sense any busy tone, they are not allowed to send the packets. If they don't sense any busy tone signal, the sender will sends data/ transmitter busy tone packet at the same time. The receiver sends its busy tone signal once it receives the data packet and the sender stops sending its busy tone packet.

In [13] the authors have proposed a new power assignment scheme for RTS/CTS-based MAC protocols, which can minimize the transmission floor of a given link. T.-S. Kim and S.-L Kim [14] have compared the random power control and the fixed power control and find that randomizing the transmission power has positive effect of reducing high interferences to the other nodes, and improves network connectivity, in high-density networks.

In [15], instead of alternating between the transmission of control (RTS/CTS) and data packets, as done in the 802.11 scheme, POWMAC used an Access Window (AW) to allow for a series of request-to-send/clear-to-send (RTS/CTS) exchanges to take place before several concurrent data packet transmissions can commence. The length of the AW is dynamically adjusted based on localized information to allow for multiple interference-limited concurrent transmissions to take place in the same vicinity of a receiving terminal. Collision avoidance information is inserted into the CTS packet and is used to bound/ the transmission power of potentially interfering terminals in the vicinity of the receiver, rather than silencing such terminals.

In [16], the authors have proposed an adaptive mechanism to dynamically choose a suitable ATIM window size. We also allow the nodes to stay awake for only a fraction of the beacon interval following the ATIM window. On the other hand, IEEE 802.11 DCF mode requires the nodes to stay awake either for the entire beacon interval following the ATIM window or none at all.

Different authors have proposed different methods to improve the spatial reusability in Mobile Ad Hoc Networks. Since effective spatial reuse plays an important role in the throughput enhancement of ad hoc networks, a detailed study of spatial reuse enhancement is done. The power control MAC protocols have reduced the power consumption of the nodes, but degraded the throughput of the network because of several reasons. Improving the spatial reuse is the best approach to improve the throughput while we using the power control MAC protocols. Some of the good concepts for the improvement in spatial reuse are discussed below.

On the basis of theoretical analysis, the authors of [17] have proposed a dynamic joint control (JC) mechanism to adjust transmit power, sense threshold and data rate, based on the former transmit status, to increase the level of spatial reuse and improve performance in terms of aggregate throughput and energy efficiency.

In [18] the authors have developed a distributed MAC algorithm, named Collision-Aware DCF (CAD), in which each node reserves only the smallest possible area which is enough to protect it and the ongoing communications and thus helps increase the spatial reuse. A unique feature of CAD is that spatial and time reservation requirement is embedded in the PHY header rather than in the MAC header. The PHY header is transmitted at the lower rate. So it guarantees that the information is delivered to a larger group of neighbouring nodes. In such a manner CAD eliminates the need for virtual carrier sensing EIFS based spatial reservation.

1.4 Thesis Organization

The thesis is organized as follows. In chapter 2, MANET Characteristics, MAC protocols in MANET etc are discussed. In Chapter 3 Various approaches for power conservation are discussed. In Chapter 4, proposed approach is discussed in detail and simulation results are placed.Finally Chapter 5 discusses the concluding remarks and future research work.

Chapter 2

Mobile Adhoc Network

Chapter 2

Mobile Ad hoc Network

2.1 Introduction

A mobile ad hoc network (MANET), is a self-configuring infrastructure less network of mobile devices connected by wireless links [19]. They offer quick and easy network deployment in situations where it is not possible otherwise. Ad-hoc is a Latin word, which means "for this only." Mobile ad hoc network is an autonomous system of mobile nodes connected by wireless links. Each node operates as an end system and a router for all other nodes in the network. Nodes in mobile ad hoc networks are free to move and organize themselves in an arbitrary fashion. Each node is free to roam about while communication with others. The path between each pair of the nodes may have multiple links and the radio between them can be heterogeneous. An ad hoc network is similar to a cellular network but is not infrastructure based, i.e., there are no coordinator or base stations present in an ad hoc network. In a cellular network base stations are present. So if a node A want to communicate with node B, the communication is carried out through a base station. But such a base station is not present in ad hoc networks. The absence of a base station makes the routing more complex in ad hoc networks compared to cellular networks. Figure 2.1 shows the communication between nodes in a cellular network and an ad hoc network.

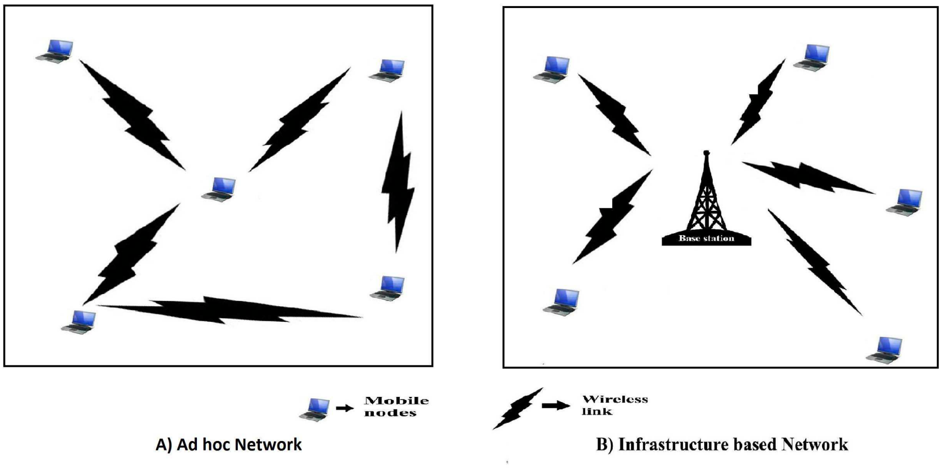

Figure 2.1: Communication in Ad Hoc and Infrastructure Based Networks

The major differences between the cellular network and the ad hoc networks are shown in Table 2.1 In an ad hoc network, the routing and resource management are done in a distributed manner in which all nodes coordinate to enable communication among them. This requires each node to be more intelligent so that it can act both as a network host and a router. Hence the mobile nodes in ad hoc networks are more complex than that in cellular networks.

Cellular Networks	**Ad Hoc Networks**
Infrastructure Based	Infrastructure less
Single hop wireless links	Multi hop wireless links
Guaranteed bandwidth	Shared Radio channel
Easier to achieve time synchronization	Time synchronization is difficult and consumes bandwidth
Easier to employ bandwidth reservation	Bandwidth reservation requires complex MAC protocols
High cost and time of deployment	Quick and cost effective deployment
Reuse of frequency spectrum through geographical channel reuse	Dynamic frequency reuse based on carrier sense mechanism

Table 2.1: Difference between cellular and ad hoc networks

2.2 Design Issues of Mobile Ad Hoc Networks

The major design issues of a mobile ad hoc network are:

- **Medium Access Scheme**
  The main responsibility of a MAC protocol in ad hoc network is the distributed arbitration of shared channel for transmission of packets. There are a lot of issues we have to consider while designing a MAC protocol. Some of them are as follows. We need to find solution for hidden and exposed terminal problems should try to improve the throughput of the system, should minimize the packet transmission delay etc. Support for power control at the MAC layer is very important in the ad hoc network environment. A MAC protocol should be able to provide mechanisms for resource reservation, real time traffic support and Qos

- **Routing**
  The major responsibilities of a routing protocol include exchanging the route information, finding a feasible path based on different criteria, gathering information about path break, utilizing minimum band width etc. The challenges that a routing protocol faces are mobility, bandwidth constraint, shared channel etc. It should provide security and privacy, minimum control overhead, scalability and Qos.

- **Quality of Service Provisioning**
  QoS is a performance level of service offered by a network. Rendering QoS in ad hoc networks can be on a per flow, per link or per node basis. QoS parameters change from application to applications. Security, reliability, availability, delay and channel utilization are the common QoS parameters

- **Self organization**

  An important property that an ad hoc network should exhibit is organizing and maintaining the network by itself. The major activities required to perform the self organization are neighbour discovery, topology organization and topology reorganization.

- **Security**

  The lack of central coordination and shared wireless medium makes the mobile ad hoc networks vulnerable to attacks. So the security of communication is more important in ad hoc networks. Denial of service attack, resource consumption attacks, information disclosure attack and interference attacks are the common security threats exists in ad hoc networks.

- **Energy Management**

  Energy management is the process of managing the sources and consumers of energy in a node or in a network as a whole for enhancing the life time of the network. Energy management can be classified into transmission power management, battery energy management, processor power management and devices power management.

2.3 MAC Protocols for Mobile Ad Hoc Networks

Nodes in an ad hoc network share a common broadcast channel. Since the bandwidth available for communication in such networks is limited, access to this shared medium should be controlled in such a manner that all nodes receive a fair share of the available bandwidth. A different set of protocols is required for controlling the access to shared medium in ad hoc networks, because they need to address unique issues such as mobility, limited bandwidth, hidden and exposed terminal problems etc. [20–23] surveys different MAC protocols for Mobile ad hoc networks and wireless LANs.

Issues in Designing a MAC Protocol:

The major issues [24] that need to be addressed while designing a MAC protocol for mobile ad hoc networks are:

Bandwidth Efficiency: Bandwidth efficiency is defined as the ratio of the bandwidth used for actual data transmission to the total available bandwidth. The MAC protocol should designed in such a way that the bandwidth is utilized in an efficient manner. The control overhead involved must be kept as minimal as possible.

Quality of Service Support: Since nodes are usually mobile in ad hoc networks, providing QoS support to data sessions is extremely difficult. QoS support is essential for supporting time critical traffic sessions. The MAC protocol for ad hoc networks that are to be used in real time application must have some kind of a resource reservation mechanism that takes into consideration the nature of the ad hoc networks.

Synchronization: Synchronization is much important for bandwidth reservation by nodes. The MAC protocols should consider the synchronization between nodes in the network. Exchange of control packets may be required for achieving time synchronization among nodes. The control packets must not consume too much of network bandwidth.

Mobility of Nodes: Nodes in an ad hoc network are mobile most of the time. The MAC protocol has no role to play in influencing the mobility of nodes. But the protocol design should take mobility factor into consideration so that the performance is not significantly affected due to node mobility.

Error Prone Shared Broadcast Channel: When a node is receiving data, no other node in its neighbourhood, other than the transmitter, should transmit.

A node must get access to the shared medium only when its transmission do not affect any ongoing session. A MAC protocol must grant channel access to nodes in such a manner that collisions are minimized.

Lack of Central Coordination: Ad hoc networks do not have centralized coordinators. Therefore, nodes should be scheduled in a distributed fashion for access the channel. It requires the exchange of control information. The MAC protocol should make sure that the overhead occurred due to this control information exchange is not very high.

Hidden and Exposed Terminal Problem: The hidden terminal problem refers to the collision of packets at a receiving node due to the simultaneous transmission of those nodes that are not within the direct transmission range of receiver. The exposed terminal problem refers to the inability of a node, which is blocked due to transmission by a nearby transmitting node, to transmit to another node. For example in Figure 2.2, if both node S1 and S2 transmit to node R1 at the same time, their packets will collide at R1. It is an example of hidden terminal problem. Consider the same figure for exposed terminal problem. Here if node S1 transmits to R1, node S3 cannot transmit to node R2.

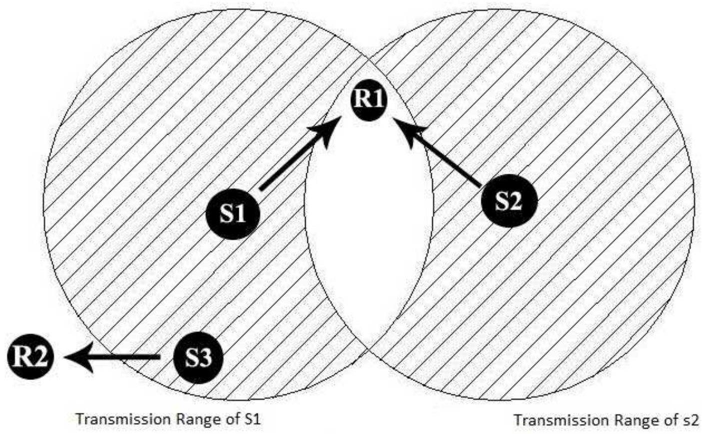

Figure 2.2: Hidden and Exposed terminal problem

2.3.1 Classification of MAC Protocols

Based on different criteria such as initiation approach, time synchronization and reservation approaches, MAC protocol can be classified into 3 basic categories:

Contention Based Protocols:

These protocols follow a contention based channel access policy. Nodes do not make any resource reservation a priori. Whenever it receives a packet to be transmitted, it contends with its neighbour nodes for access to the shared channel. This protocol does not guarantee the QoS. Contention based protocols can be further classified into sender initiated and receive initiated. Sender initiated can be further divided into single channel sender initiated and multi channel sender initiated. In single channel sender initiated, the node who wins the contention can use the entire bandwidth. But in case of multi channel, the available bandwidth is divided into multiple channels which enable several nodes to simultaneously transmit data, each using separate channel.

Contention Based Protocol with Reservation Mechanisms:

Contention based protocols does not support real time traffic since nodes do not guarantee periodic access to the channel. For supporting such traffic, some protocols have mechanisms for reserving bandwidth a priori. These protocols can be classified into two: Synchronous protocols which require time synchronization among all nodes and asynchronous protocols which do not require any global synchronization among nodes.

Contention Based Protocol with Scheduling Mechanisms:

These protocols focus on the packet scheduling at nodes, and also scheduling nodes for access to the channel. Node scheduling is done in such a manner that all nodes are treated fairly and no nodes are starved of bandwidth. Some scheduling schemes consider the battery characteristics while scheduling nodes for access to the channel.

2.3.2 IEEE 802.11 MAC Protocol

IEEE 802.11 specifies two medium access control schemes, PCF and DCF. PCF is a centralized scheme, when DCF is a fully distributed scheme. DCF is based on CSMA/CA. When the station has packet to transmit, it senses the channel by Physical Carrier Sense (PCS) and Virtual Carrier Sense (VCS). PCS notifies the MAC layer if there is a transmission going on and VCS is NAV procedure. If NAV is set to a number, station waits until it resets to zero. Virtual carrier sensing uses the duration of the packet transmission included in the header of RTS, CTS and DATA frames. The duration included in each of these frames can be used to infer the time when the source node would receive an ACK frame from the destination node. The duration of RTS frame includes the time for CTS, DATA and ACK transmissions while that of CTS includes time for DATA and ACK transmissions. Similarly the duration field of DATA only includes the duration for the ACK transmission.

Each node in IEEE 802.11 maintains a NAV, which indicates the remaining time of the ongoing transmission sessions. Nodes will update their NAV using the duration information in RTS, CTS and DATA packets after they receive a packet. The channel is considered as busy if either PCS or VCS indicates that channel is busy.

The time intervals between frames are specified as Inter Frame Spaces (IFS). IEEE 802.11 specifies four IFSs named SIFS, PIFS, DIFS and EIFS. The SIFS is the shortest among the IFS and is used after RTS, CTS and DATA frames to give the highest priority to CTS, DATA and ACK frames respectively. When a channel is idle, a node waits for DIFS duration before transmitting a packet.

Nodes in the transmission range correctly set their NAVs when receicving RTS or CTS. Since nodes in carrier sensing zone is not able to decode the packet, they do not know the duration of the packet transmission. So, to prevent the collision at the source node with the ACK, the nodes set their NAVs for the EIFS duration. The purpose of EIFS is to provide enough time for a source node to receive the ACK. EIFS is obtained using the SIFS, DIFS and the length of time to transmit an ACK at physical layer's lowest mandatory rate. These process is shown in the following figure.

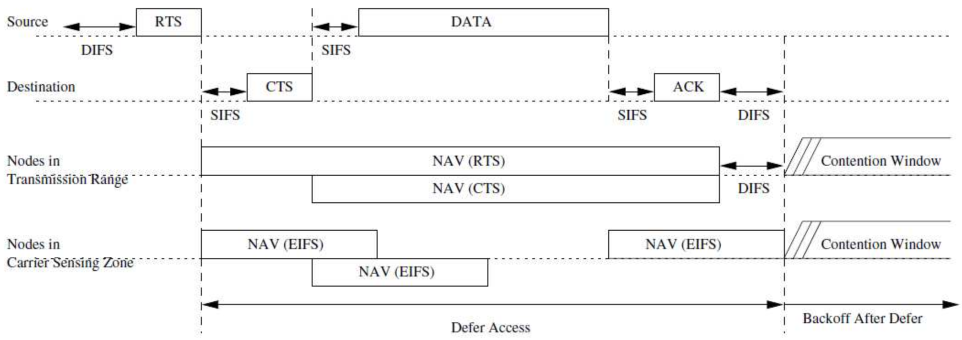

Figure 2.3: The nodes in the transmission range and carrier sensing range set their NAV

Chapter 3

Power Conservation in MANET

Chapter 3

Power Conservation in MANET

3.1 Introduction

Since nodes in an ad hoc network are limited battery powered, power management is an important issue in such networks. Battery power is a precious resource that should be used effectively in order to avoid the early termination of nodes. Power management deals with the process of managing resources by means of controlling the battery discharge, adjusting the transmission power, and scheduling of power sources so as to increase the life time of nodes in the ad hoc networks. Battery management, transmission power management and system power management are three major methods to increase the life time of nodes.

3.2 Need for Power Management in Ad Hoc Networks

The main reasons for power management in ad hoc networks are the following:

Limited Energy Reserve: The main reason for the development of ad hoc networks is to provide a communication infrastructure in environments where the setting up of fixed infrastructure is impossible. Ad hoc networks have very limited power resources. The increasing gap between the power consumption requirements and power availability adds to the importance of energy management. Difficulties in Replacing Batteries: In some situations, it is very difficult to replace or recharge batteries. Power conservation is essential in such situations.

Lack of Central Coordination: The lack of central coordination necessitates some of the intermediate node to act as relay nodes. If the proportion of relay traffic is more, it may lead to a faster depletion of power source.

Constraints on the Battery Source: Batteries will increase the size of the mobile nodes. If we reduce the size of the battery, it will results in less capacity. So in addition to reducing the size of the battery, energy management techniques are necessary.

Selection of Optimal Transmission Power: The transmission power determines the reachability of the nodes. With an increase in transmission power, the battery charge also will increase. So it is necessary to select an optimum transmission power for effectively utilize the battery power.

Channel Utilization: The frequency reuse will increase with the reduction in transmission power. Power control is required to maintain the required SIR at receiver and to increase the channel reusability.

3.3 Power Conservation Approaches

Two mechanisms affect energy consumption: power control and power management [25]. If these mechanisms are not used wisely, the overall effect could be an increase in energy consumption or reduced communication in the network.

3.3.1 Power Control

The aim of communication-time power conservation is to reduce the amount of power used by individual nodes and by the aggregation of all nodes to transmit data through the ad hoc network. Two components determine the cost of communication in the network. First one is direct node to node communication or transmission. The transmission rate can be adapted by the sender [26]. Second is forwarding of data through the networks. In the first case we can use the power control techniques to conserve the power. Whereas in the second case we can use the energy efficient routing schemes.

Current technology supports power control by enabling the adaptation of power levels at individual nodes in an ad hoc network. Since the power required transmitting between two nodes increases with the distance between the sender and the receiver, the power level directly affects the cost of communication. The power level defines the communication range of the node and the topology of the network. Due to the impact on network topology, artificially limiting the power level to a maximum transmit power level at individual nodes is called topology control. MAC layer protocols coordinate all nodes within transmission range of both the sender and the receiver. In the MAC protocols, the channel is reserved through the transmission of RTS and CTS messages. Node other than the destination node that hears these messages backs off, allowing the reserving nodes to communicate undisturbed. The power level at which these control messages are sent defines the area in which other nodes are silenced, and so defines the spatial reuse in the network [27–29]. Topology control determines the maximum power level for each node in the network. So topology control protocols minimize power levels increase spatial reuse, reducing contention in the network and reducing energy consumption due to interference and contention. The use of different power levels increases the potential capacity of the network.

Once the communication range of a node has been defined by the specific topology control protocol, the power level for data communication can be determined on a per-link or even per-packet basis. If the receiver is inside the communication range defined by the specific topology control protocol, energy can be saved by transmitting data at a lower power level determined by the distance between the sender and the receiver and the characteristics of the wireless communication channel [30].

Power aware routing reduces the power consumption by finding the power efficient routes. At the network layer, routing algorithms must select routes that minimize the total power needed to forward packets through the network, so-called minimum energy routing [31]. Minimum energy routing is not optimal because it leads to energy depletion of nodes along frequently used routes and causing network partitions.

3.3.2 Power Management

Idle-time power conservation spans across all layers of the communication protocol stack. Each layer has different mechanisms to support power conservation. MAC layer protocols can save the power by keeping the nodes in short term idle periods. Power management protocols integrate global information based on topology or traffic characteristics to determine transitions between active mode and power-save mode. In ad hoc networks, the listening cost is only slightly lower than the receiving cost [32]. Listening costs can be reduced by shutting off the device or placing the device in a low-power state when there is no active communication. The low-power state turns off the receiver inside the device, essentially placing the device in a suspended state from which it can be resumed relatively quickly. But the time taken to resume a node from completely off state is much more and may consume more energy.

The aim of any device suspension protocol is to remain awake the node when there is active communication and otherwise suspend. Since both the sender and receiver must be awake to transmit and receive, it is necessary to ensure an overlap between awake times for nodes with pending communication.

Different methods such as periodic resume and triggered resume can be used when to resume a node to listen the channel. In periodic resume, the node is suspend the nodes most of the time and periodically resumes checking if any packet destined to it. If a node has some packets destined for it, it remains awake until there are no more packets or until the end of the cycle.

In triggered resume method to avoid the need for periodic suspend/resume cycles, a second control channel can be used to tell the receiving node when to wake up, while the main channel is used to transmit the message.

Chapter 4

Proposed Approach

Chapter 4

Proposed Approach

4.1 Motivation

Power control is an important thing in the 802.11 based Mobile Ad hoc Networks, because most of the equipments in MANETs are battery powered. So we have to reduce the power consumption of each and every node. There are several methods to reduce the power consumption of nodes. An effective method is sending the packets with optimum power.

In power control protocols, since nodes use different power for different transmissions, there is a chance to reduce the throughput of the entire network. A power control protocol can improve the throughput over IEEE 802.11 by creating better spatial reuse in the network. In order to alleviate the throughput degradation problem, we improve the virtual carrier sensing approach used in IEEE 802.11. It improves the throughput of our network.

Protocol Assumptions Our main motivation is to reduce the power consumption of each and every node. In addition to it we should have to improve the aggregate throughput

4.2 Protocol Assumptions and System Model

In this model, nodes are randomly deployed in a geographical area. It is assumed that nodes are stationary, homogeneous and use Omni directional antenna for transmission. The other assumptions we used in our protocol are as follows.

The gain between two nodes is same in both directions. The channel gain is stationary for the duration of the control and data packet transmission periods. The propagation model used is the two ray ground reflection model [33]. The relationship between transmitted power and the received power can be represented as follows:

$$P_r = P_t * G_{tr}$$

Where, G_{tr} is the gain from the transmitter to the receiver.
The received power at a distance d can be calculated as:

$$P_r = \frac{P_t G_t G_r H_t^2 H_r^2}{d^4 L}$$

Where, H_t and H_r are heights of transmitter and receiver antennas and is same for every antenna. L is the system loss factor which is set to 1.

4.3 Protocol Description

Our protocol is a power control MAC protocol with improved throughput. Our aim was to reduce the power consumption of each node in the network and in addition to it improve the aggregate throughput of the network. The protocol is organised as two phases. The first phase is used to reduce the power consumption of nodes and the second phase for improving the throughput of the network.

4.3.1 Reduce the power consumption

Like most of the power control protocols, here also the power can be reduced by send the packets with optimum power. All of the existing power control MAC protocols were sending the RTS and CTS packets with maximum (default) power and the DATA and ACK packets using the minimum power. Instead of this, here we send the RTS with default power and CTS, DATA and ACK packets with optimum power.
This protocol requires the addition of a field to the RTS and CTS control packets. The structure of the existing and proposed RTS packet is as shown below:

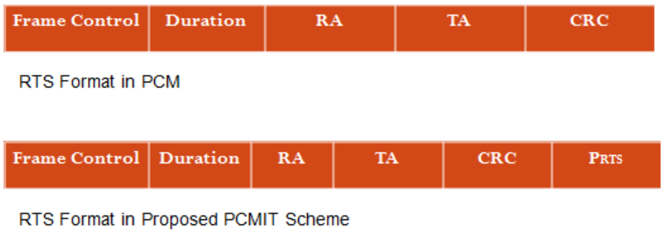

Figure 4.1: Structure of RTS Frames

The structure of the existing and proposed CTS packet is as shown below:

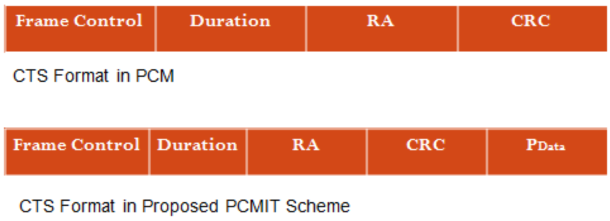

Figure 4.2: Structure of CTS Frames

The working procedure of the protocol is described as follows:

- The transmitter send the RTS packet containing the value of P_{RTS} at a transmitted power level P_{RTS}.
- The receiver will receive the RTS frame at a received power P_r.
- The receiver will take the RTS transmitted power P_{RTS} from the received RTS packet.
- After determining the P_{RTS} and P_r, the CTS transmision power P_{CTS} and data transmission P_{Data} can be calculate.
- The receiver sends out the CTS containing the value of P_{Data} at a transmitted power P_{CTS}.
- The transmitter will send the data frames to the receiver at the transmitted power P_{Data} which is the value obtained from the P_{Data} field of the immediately previous CTS frame.

- The receiver after receiving the DATA frame will send an ACK frame with a power that is used to send the CTS frame.

Using P_{RTS} and Pr, the CTS transmission power P_{CTS} can be calculated as follows:

$$P_{CTS} = \frac{P_{RTS}}{P_r} * R_{th}$$

Where, R_{th} is the receiving threshold (minimum signal strength at which the receiver can decode the signal)
After calculating the P_{CTS}, that value will assigned to the P_{Data} field of the CTS frame and the CTS frame will send with the power P_{CTS}.

4.3.2 Improve the Throughput

In 802.11 virtual carrier sensing mechanism, if a node overhear an RTS or CTS packet, the node which over hear the packet assumes the channel as busy and set its Network Allocation Vector (NAV). Thus if that over heard node has any packet to send, it defer the transmission for a duration. Here we improved this virtual carrier sensing mechanism.
A node can over hear an RTS packet only or a CTS packet only or can overhear both RTS and CTS packet. In our protocol since the CTS transmission range is less compared to the RTS transmission range. So there is a chance that a node overhears RTS packets only. Suppose a node over hear the RTS packet only and it has a CTS packet to send, it will send that packet immediately. It is possible because it won't affect the ongoing transmission.
For example consider the following figure,
Here, node A has data to send to node B. So it sends an RTS packet to B. Since C is in the RTS transmission range of A, it will overhear the RTS packet. After receiving the RTS packet node send will respond by a CTS frame. Since the CTS transmission range of B is small, that CTS packet won't overhear by node C. So it won't set its NAV. So if C receives an RTS packet from D, it can respond immediately with a CTS packet. It will improve the spatial reuse, because more nodes can send packets at a time. Thus it will improve the throughput of

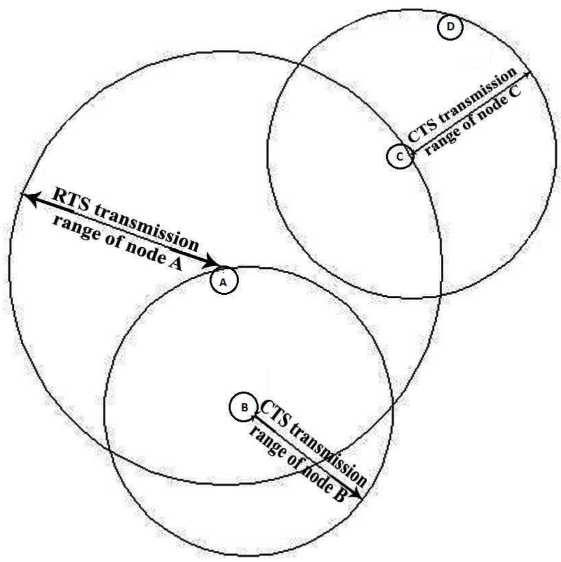

Figure 4.3: RTS and CTS transmission ranges

the network. For this purpose we make some modifications in the VCS scheme present in the IEEE 802.11 MAC.

The Modified VCS Scheme

The Figure 4.4 shows the setting of NAV in 802.11 and proposed scheme. The modified Virtual Carrier Sensing Scheme is discussed as follows:

- In addition to NAV used in 802.11 MAC VCS, we use another parameter NAVR

- If a node in the transmission range overhears an RTS frame, it will set its NAV to a slot time and the NAVR to the value in the duration field of RTS frame received. A slot time is the time it takes a node to recognise a channel as busy or idle plus the time it takes to process a frame, prepare a response, and transmit it and for it to propagate to the receiving station.

- If the node overhears the CTS frame before the NAV expires, it will set the NAV using the value in the duration field of the CTS frame.

- If the node in the transmission range wants to send a frame, it will check

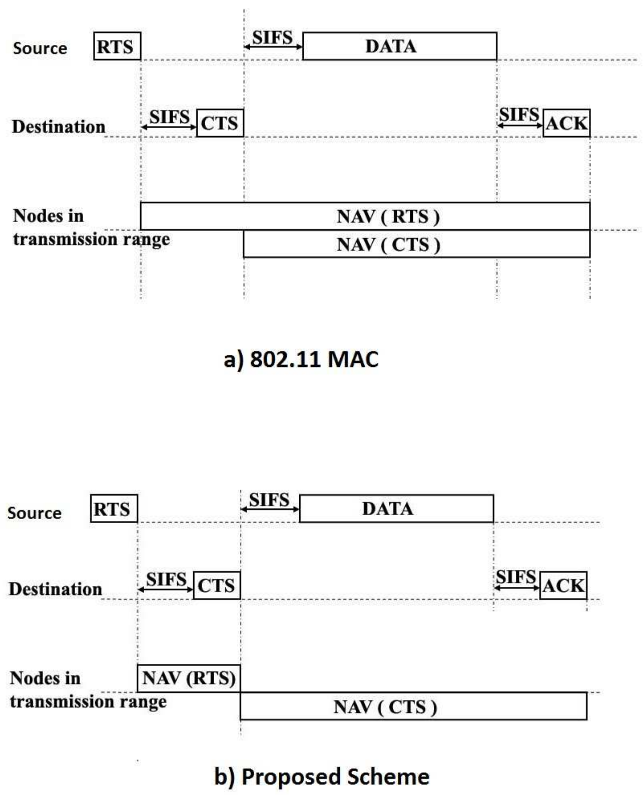

Figure 4.4: Setting the NAV in 802.11 and Proposed Scheme

the frame type.

- If it is an RTS frame it will check if NAVR expires or not. If NAVR expires, it can send the RTS frame. Otherwise it will wait for a back off time. If it is a CTS, DAT or ACK frame, it will check the NAV and if NAV expires to zero, it can send that frame.

4.4 Simulations and Experimental Results

4.4.1 Scenario Setup

We implemented our PCMIT on Qualnet 4.5 network simulator with AODV as routing protocol. The metrices we mainly focused are Power consumed and Throughput. We setup scenario with a Terrain size 1000mx1000m and place 50 nodes in it.The node placement strategy used is random.The packet size used is 512 bytes. We simulated the same scenario using both PCM and proposed concept and observed changes in power consumption and Throughput. We repeated the experiment with scenarios having different packet size for both PCM and the proposed protocol. In all scenarios, application is made between source node 1 and destination node 50. The table 4.1 shows the different configuration parameters used to setup the scenario.

Terrain	1000mx1000m
Number of Nodes	50
Application	CBR
Packet size	512
No of packets	100
Routing Protocol	AODV
Node Mobility	None(Stable)
Antenna Model	Omni directional

Table 4.1: Simulation parameters

4.4.2 Qualnet Network Simulator

QualNet Developer is a tool created improve the design, operation, and management of networks. QualNet Developer is a comprehensive suite of tools for modeling large wired and wireless networks. It predicts performance of networking protocols and networks through simulation and emulation. Using emulation and simulation it allows reproducing the unfavorable conditions of networks in a controllable and repeatable lab setting QualNet is a fast, scalable and hi-fidelity network modeling software. It enables very efficient and cost-effective development of new network technologies [34].

Key features of Qualnet

- **Speed** Qualnet can support real-time and faster than real-time simulation speed, which enables software-in-the-loop, network emulation, hardware-in-the-loop, and human-in-the-loop exercises.
- **Scalability** QualNet supports thousands of nodes. It can also take advantage of parallel computing architectures to support more network nodes and faster modeling. Speed and scalability are not mutually exclusive with QualNet.
- **Model Fidelity** QualNet offers highly detailed models for all aspects of networking. This ensures accurate modeling results and enables detailed analysis of protocol and network performance.
- **Portability** QualNet runs on a vast array of platforms, including Linux, Solaris, Windows XP, and Mac OS X operating systems, distributed and cluster parallel architectures, and both 32- and 64-bit computing.
- **Extensibility** QualNet connects to other hardware & software applications, such as OTB, real networks, and STK, greatly enhancing the value of the network model.

Figure 4.4 shows the runtime scenario of simulation for Proposed protocol. The path represented in the scenario represents the route through which packet travelled from source node 1 to destination node 50

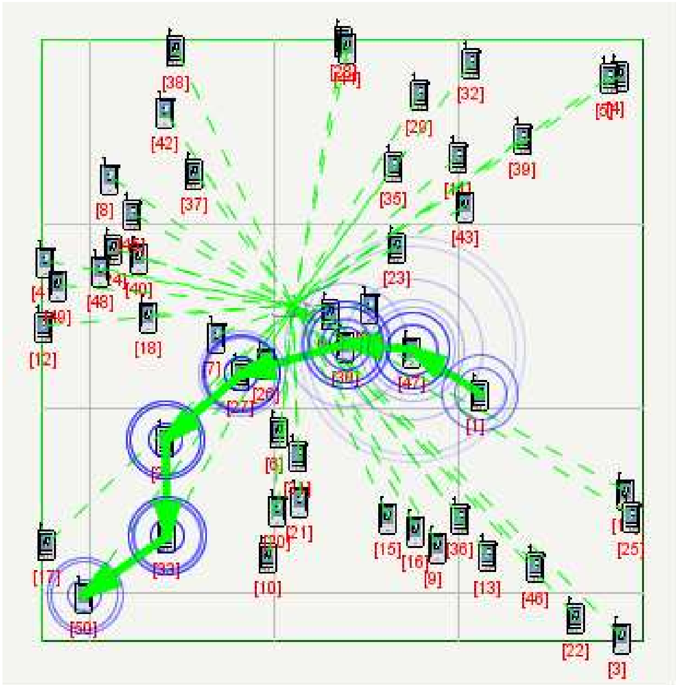

Figure 4.5: Run time scenario for Proposed Protocol

Figure 4.5 to 4.8 shows the statistics obtained at the end of simulation.Figure4.5 and 4.6 shows power consumed for the simulation of PCM protocol and the proposed protocol respectively. As shown in the results there is a difference in the power consumption between the two concepts. the power consumption in PCMIT is less compared to that of PCMIT.

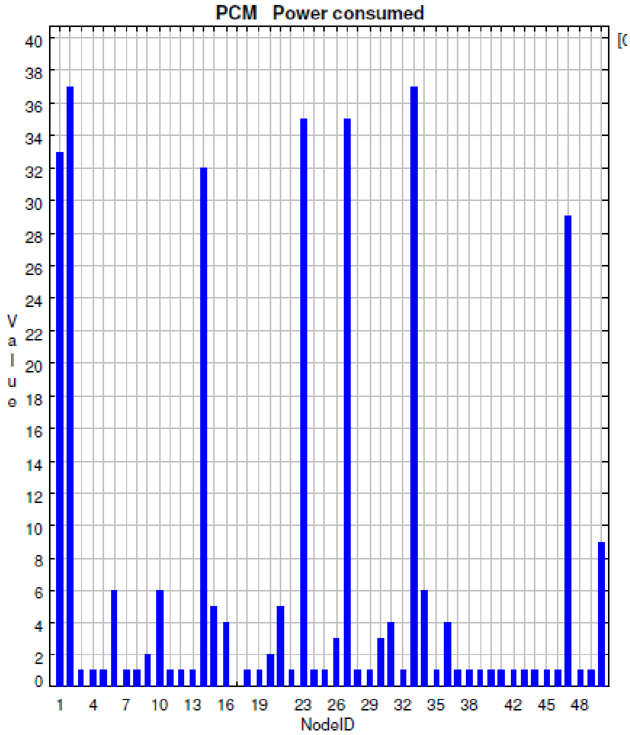

Figure 4.6: Power consumption of each node in PCM

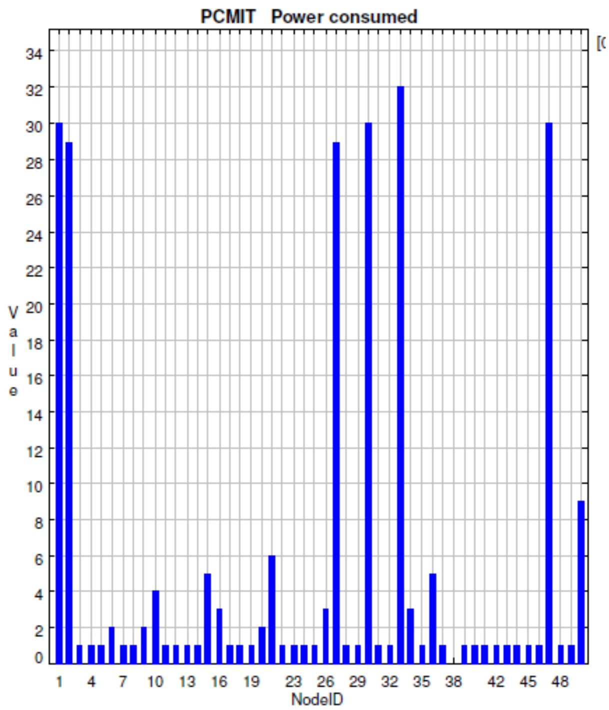

Figure 4.7: Power consumption of each node in Proposed scheme

Figure 4.7 shows the comparison between the power consumed in the existing power control protocol and the proposed approach.

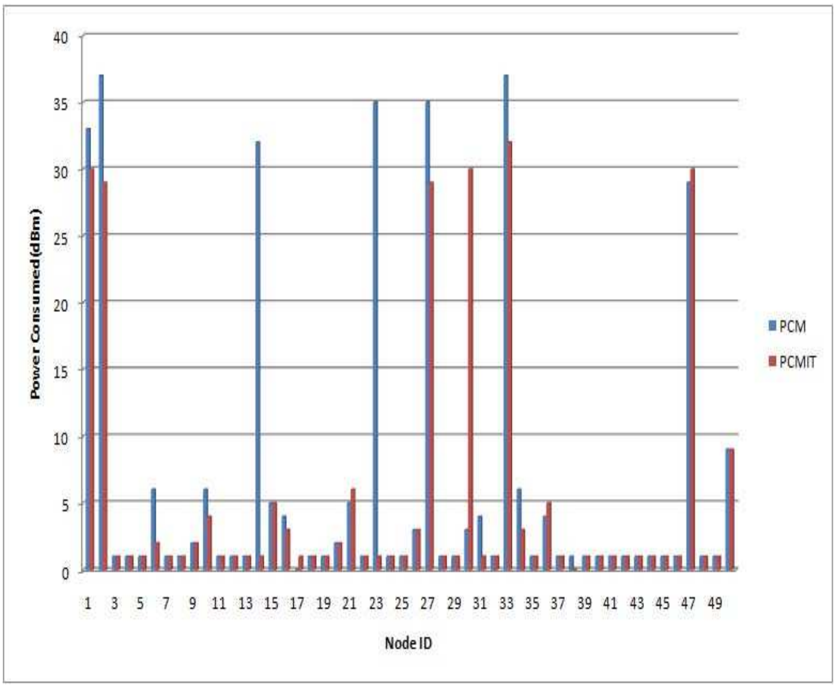

Figure 4.8: Power consumption of each node in PCM vs Proposed Scheme

Now we run the same scenario with different packet size and analyze the throughput obtained in each run. Then we plot a graph which compare the throughput obtained in PCM and proposed scheme for different packet size. Figure 1.7 shows the comparison of throughput for the existing and our proposed protocol. We can find that the throughput of proposed scheme increased compared to that of PCM.

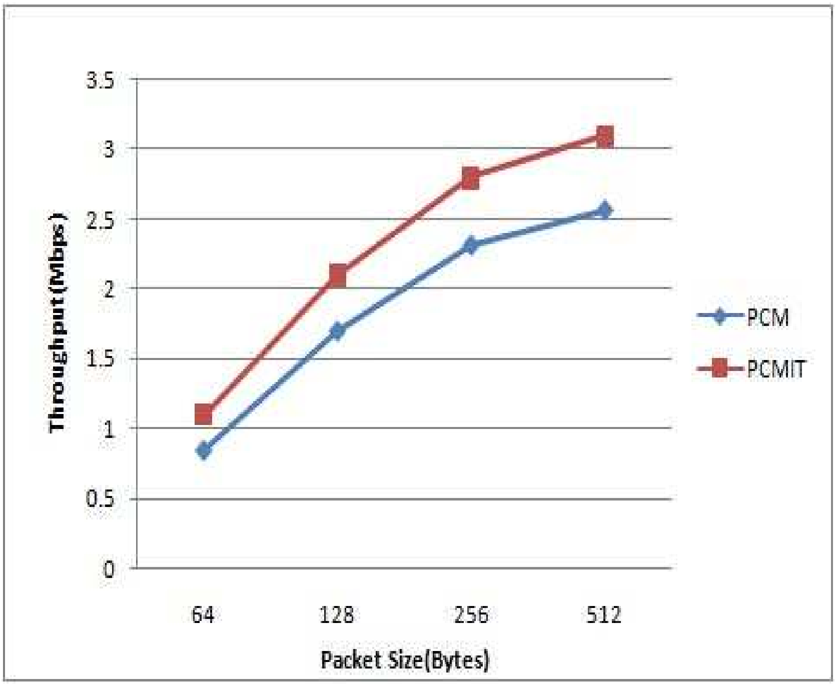

Figure 4.9: Throughput obtained in PCM and Proposed scheme for different packet sizes

Chapter 5

Conclusions and Future Work

Main Contributions

Future Work

Chapter 5

Conclusion and Future Work

In this thesis we have designed a power control MAC protocol for Mobile Ad Hoc Networks. We considered a network environment where every node participate in data transmission and applied a power control concept in that environment.The main goal of this work was to understand the different power conservation techniques in MANET and propose a protocol to achieve this goal.

Here we have proposed a power control MAC protocol for mobile ad hoc networks which reduce the power consumption and increase the aggregate throughput. We have modified the 802.11 MAC protocol to achieve our goal. For reduce the power consumption we havebused the transmission power control techniques. For improve the throughput, we need to improve the spatial reuse of the network. Improvement in spatial reuse will make more simultaneous transmission possible and which will improve the throughput of the network. For that purpose we have made some modifications in the virtual carrier sensing scheme of 802.11 MAC. This chapter concludes the thesis by summarizing the contributions and describing future directions.

5.1 Main Contributions

Battery power is a limiting factor in successful deployment of a mobile ad hoc network, since nodes are battery powered and expected to have little potential for recharging their batteries. A lot of power control protocols are proposed by different authors but most of them did not consider the throughput. The main contribution of this work is a power control MAC protocol which reduces the power consumption and also increase the throughput of the network. We hope these contributions constitute some measure of progress with respect to design and deployment of wireless network.

5.2 Future Work

In our work we consider a stable network environment. Mobility of the nodes did not take into consideration. In future works we can consider the mobility of the nodes to make it more suitable for mobile ad hoc networks.

Bibliography

[1] S. Singh and C.S. Raghavendra. Power Aware Multi-Access protocol with Signaling for Ad Hoc Networks. *ACM Comput. Commun*, 28(3):5–26, 1998.

[2] A. Chockalingam and M. Zorzi. Energy efficiency of media access protocols for mobile data networks. *IEEE Trans. Commun*, 46(11):IEEE Trans. Commun, 1998.

[3] E.-S. Jung and N.H. Vaidya. An energy efficient MAC protocol for wireless LANs. *Proceedings of the IEEE INFOCOM*, June 2002.

[4] H. Woesner, J.P. Ebert, M. Schlager and A. Wolisz. Power saving mechanisms in emerging standards for wireless LANs: the MAC level perspective. *IEEE Person. Commun*, 5(3):40–48, 1998.

[5] Y.-C. Tseng, C.-S. Hsu, T.-Y. Hsieh. Power-saving protocols for IEEE 802.11-based multi-hop ad hoc networks. *Proceedings of IEEE INFOCOM*, 2002.

[6] E.S. Jung, N.H. Vaidya. A Power Control MAC protocol for ad hoc networks. *ACM International Conference Mobile Computing and Networking (MOBICOM)*, pages 36–47, September 2002.

[7] J.P. Monks, V. Bharghavan, W. Hwu. A Power Controlled Multiple Access protocol for wireless packet networks. *Proceedings of the IEEE INFOCOM*, April 2001.

[8] Vikas Kawadia. Principles and Protocols for Power Control in Wireless Ad Hoc Networks. *IEEE Journal On Selected Areas In Communications*, 23(1):76–88, January 2005.

[9] Alexandre Andrade Pires, Jose Ferreira de Rezende and Carlos Cordeiro. ALCA: A New Scheme for Power Control on 802.11 Ad Hoc Networks. *IEEE WoWMoM*, June 2005.

[10] D. Kim, C. K. Toh. F-PCM: a fragmentation-based power control MAC protocol for IEEE 802.11 mobile ad hoc networks. *Wireless Communications and Mobile Computing*, 6(5):727–739, August 2006.

[11] A. Muqattash and M. Krunz. Power controlled dual channel (PCDC) medium access protocol for wireless ad hoc networks. *IEEE INFOCOM*, pages 470–480, April 2003.

[12] H. Cui, G. Wei, Z. Zhang and J. Zhang1. Medium access control scheme supporting real-time traffic with power control in wireless ad hoc networks. *IET Commun.*, 4(4):377–383, 2010.

[13] W. Wang , V.Srinivasan , K.C. Chua. Power control for distributed MAC protocols in wireless ad hoc networks. *IEEE Trans. Mobile Comput.*, 7(10):1169–1183, 2008.

[14] T.-S. Kim and S.-L Kim. Random Power Control in Wireless Ad Hoc Networks. *IEEE Communications Letters*, 9(12):1046–1048, December 2005.

[15] Alaa Muqattash and Marwan Krunz. POWMAC: A Single-Channel Power-Control Protocol for Throughput Enhancement in Wireless Ad Hoc Networks. *IEEE Journal on Selected Areas in Communictions*, 23(5):1067–1084, May 2005.

[16] E. -S. Jung, N. H. Vidya. An Energy Efficient MAC Protocol for Wireless LANs. *IEEE INFOCOM*, pages 1756–1764, 2002.

[17] X. Zhang, X. Yu, Y. Liu and Q. Liu. Joint Control to Improve Spatial Reuse for Mobile Ad Hoc Networks. *WiCOM*, pages 1–4, October 2008.

[18] L. Song and C. Yu. Spatial Reuse with Collision-Aware DCF in Mobile Ad Hoc Networks. *ICPP*, pages 219–228, 2006.

[19] Carlos de Morais Cordeiro and Dharma Prakash Agrawal. *Ad Hoc and Sensor Networks Theory and Applications*. World Scientific Publishing Co. Pt. Ltd, 2006.

[20] L.M. Patnaik, S. Hasan Raza Naqvi. A review of medium access protocols for mobile ad hoc networks with transmission power control. *Microprocessors and Microsystems*, 28:447–455, March 2004.

[21] S.-L. Tsao, C. -H Huang. A survey of energy efficient MAC protocols for IEEE 802.11 WLAN. *Computer Communications*, 34:54–67, 2011.

[22] Sunil Kumar, Vineet S. Raghavan and Jing Deng. Medium Access Control protocols for ad hoc wireless networks: A survey. *Ad Hoc Networks*, 4:326358, October 2006.

[23] R. Jurdak, C. V. Lopes and P. Baldi. A Survey, Classification and Comparative Analysis of Medium Access Control Protocols for Ad Hoc Networks. *IEEE Communications Surveys & Tutorials*, 6(1):2–16, 2004.

[24] C. Sivaram Murthy and B. S. Manoj. *Ad Hoc Wireless Networks, Architectures and protocols*. Pearson Education, 2 edition, 2004.

[25] P. Mohapatra and S. Krishnamurthy. *Ad Hoc Networks, technologies and Protocols*. Springer Science + Business Media, Inc., 2005.

[26] Gavin Holland, Nitin Vaidya and Paramvir Bahl. A rate-adaptive mac protocol for multi-hop wireless networks. *7th Annual International Conference on Mobile Computing and Networking (MobiCom)*, 2001.

[27] T.-C. Hou and V. Li. Transmission range control in multihop packet radio networks. *IEEE Transactions on Communications*, 34(1):38–44, January 1986.

[28] J. Li, C. Blake, D. S. J. De Couto and H. I. Lee and R. Morris. Capacity of ad hoc wireless networks. *7th Annual International Conference on Mobile Computing and Networking (MobiCom)*, 2001.

[29] C.-K. Toh. Associativity-based routing for ad hoc mobile networks. *Wireless Personal Communication*, 4(2):103139, March 1997.

[30] J. Gomez, A. T. Campbell, M. Naghshineh and C. Bisdikian. PARO: Supporting dynamic power controlled routing in wireless ad hoc networks. *Wireless Networks*, 9(5):443–460, September 2003.

[31] L. M. Feeney. An energy consumption model for performance analysis of routing protocols for mobile ad hoc networks. *Mobile Networks and Applications*, 6(3):239–249, June 2001.

[32] J.-P. Ebert, B. Burns and A. Wolisz. A trace-based aprroach for determining the energy consumption of a WLAN network interface. *In European Wireless*, 2002.

[33] Wireless Communications: Principles and Practice. *Theodore S. Rappaport.* Prentice Hall, 2nd edition, December 2001.

[34] Scalable Network Technologies Inc., http://www.scalable-networks.com. *Qualnet Documents*, 2009.